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Yokoyama et al.

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(54) **INDUCTOR ELEMENT**

(71) Applicant: **Murata Manufacturing Co., Ltd.**, Kyoto (JP)

(72) Inventors: **Tomoya Yokoyama**, Kyoto (JP); **Takako Sato**, Kyoto (JP)

(73) Assignee: **MURATA MANUFACTURING CO., LTD.**, Kyoto (JP)

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

H01F 5/00	(2006.01)
H01F 27/28	(2006.01)
H01Q 7/06	(2006.01)
H01F 17/00	(2006.01)
H01F 38/14	(2006.01)

(52) **U.S. Cl.**

CPC ***H01F 27/2804*** (2013.01); ***H01F 5/003*** (2013.01); ***H01Q 7/06*** (2013.01); *H01F 17/0033* (2013.01); *H01F 38/14* (2013.01); *H01F 2027/2809* (2013.01)

(58) **Field of Classification Search**

CPC . H01F 5/003; H01F 27/2804; H01F 17/0033; H01F 17/0013; H01F 2027/2809; H01F 38/14; H01Q 7/06

USPC 336/200, 234, 147, 223

See application file for complete search history.

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Primary Examiner — Mangtin Lian

(74) *Attorney, Agent, or Firm* — Pearne & Gordon LLP

(57) **ABSTRACT**

A multilayer body **12** includes nonmagnetic sheets SH**1***a* and SH**1***b* each having an upper surface provided with a plurality of linear conductors **16**, a magnetic sheet SH**3** having an upper surface provided with a plurality of linear conductors **18***a*, and a nonmagnetic sheet SH**4** having an upper surface provided with a plurality of linear conductors **18***b*, which are stacked one on top of another. Via-hole conductors or side-surface conductors are disposed with the multilayer body **12** so as to connect these linear conductors to one another and form an inductor. The plurality of linear conductors have a pattern that is common among at least two sheets adjacent to each other in a stacking direction.

7 Claims, 14 Drawing Sheets

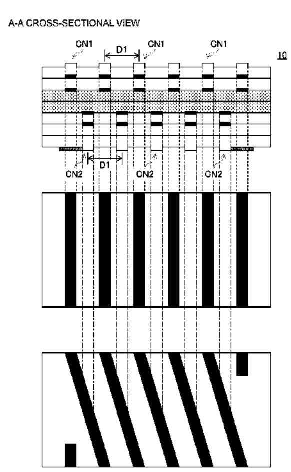

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FIG. 1

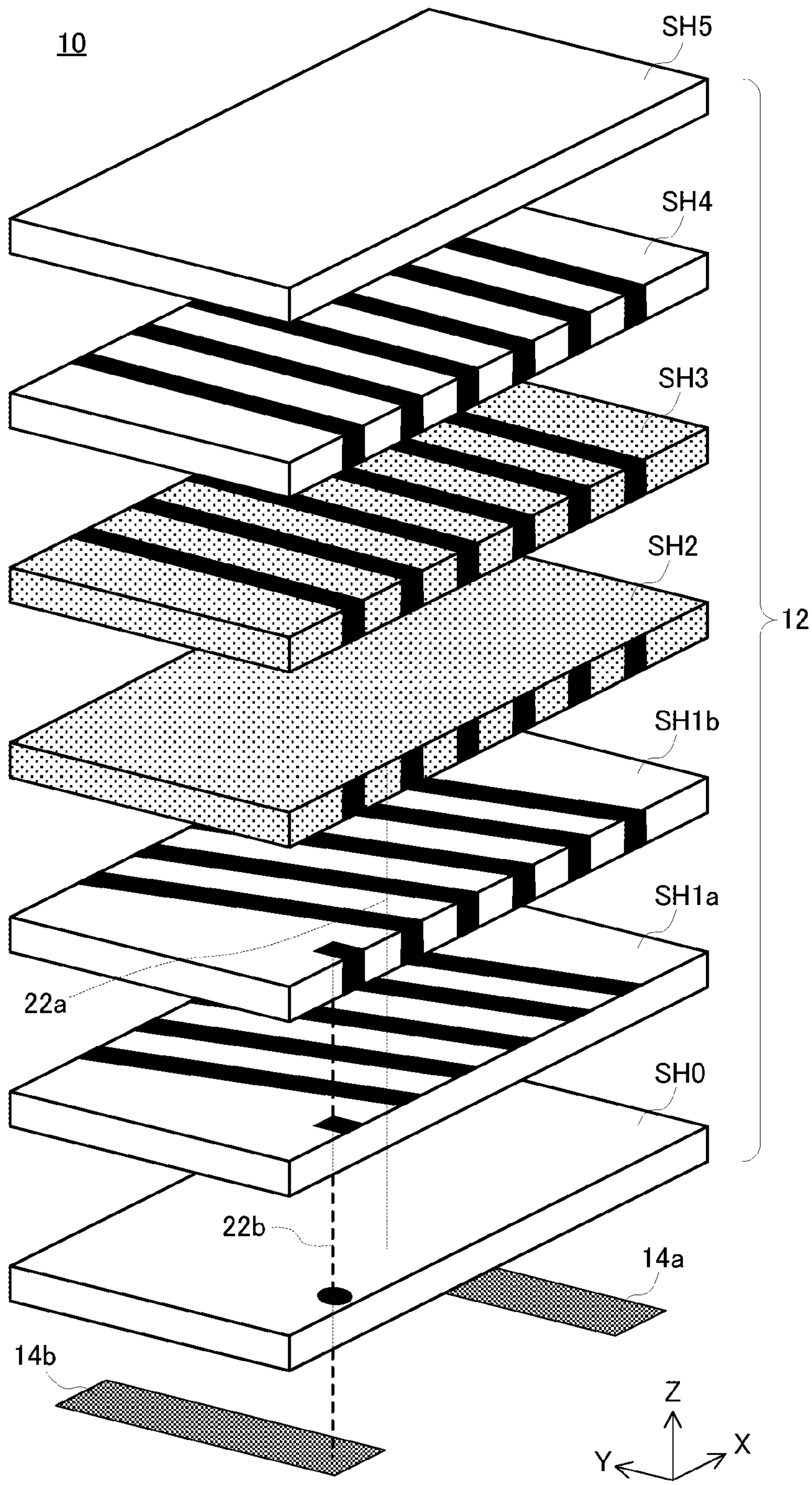


FIG. 2A

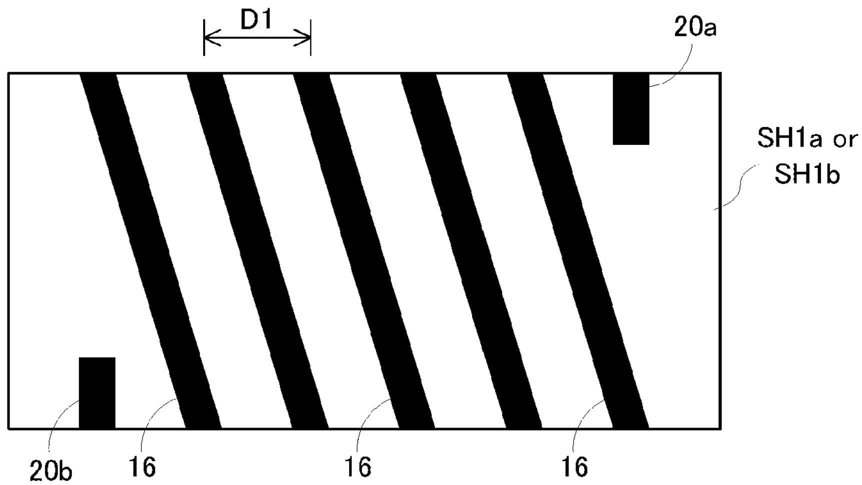


FIG. 2B

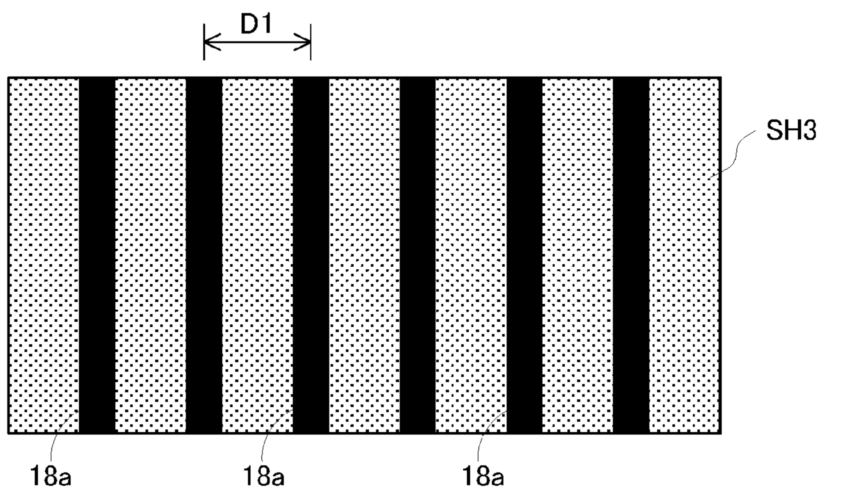


FIG. 2C

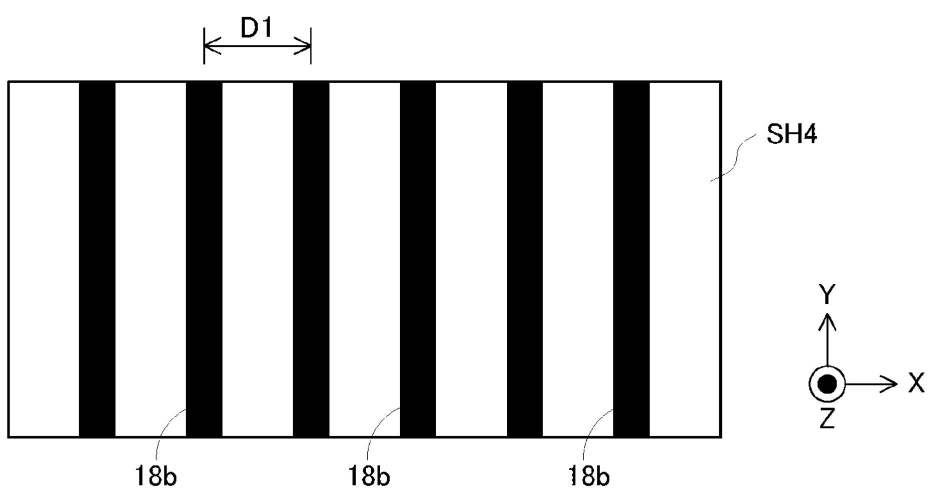


FIG. 3

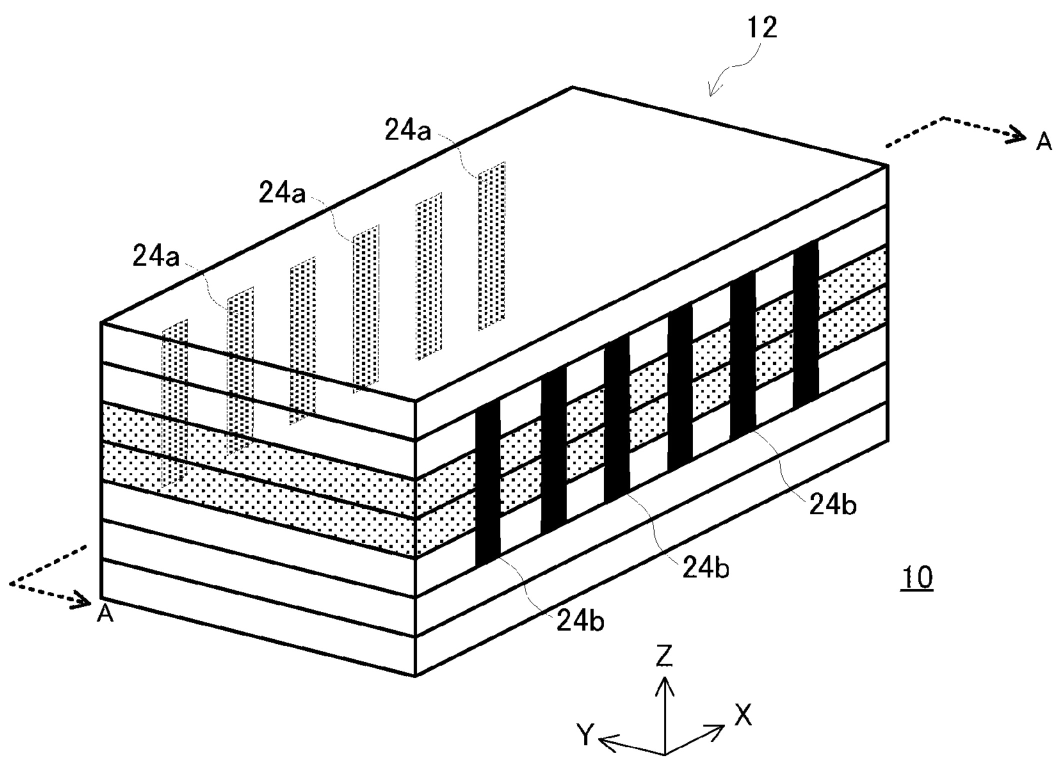


FIG. 4

A-A CROSS-SECTIONAL VIEW

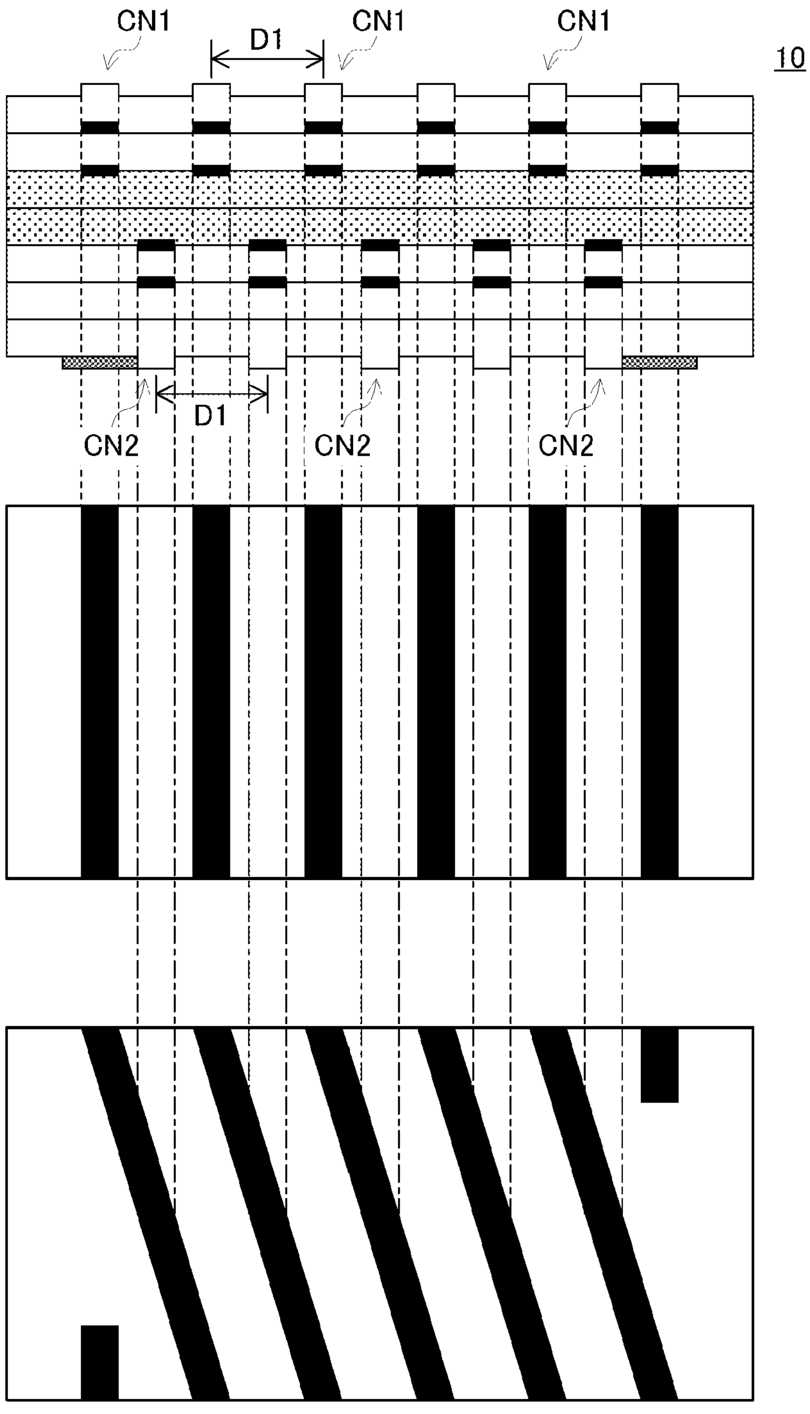


FIG. 5A PREPARE MOTHER SHEET

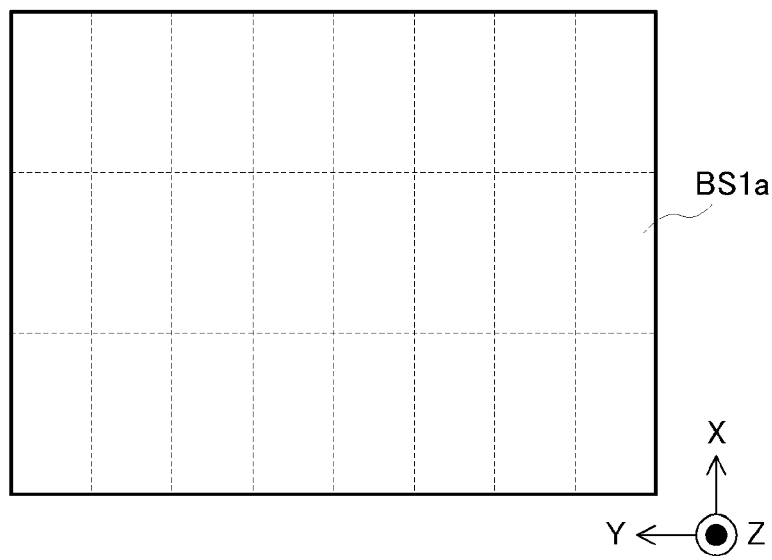


FIG. 5B FORM THROUGH-HOLES

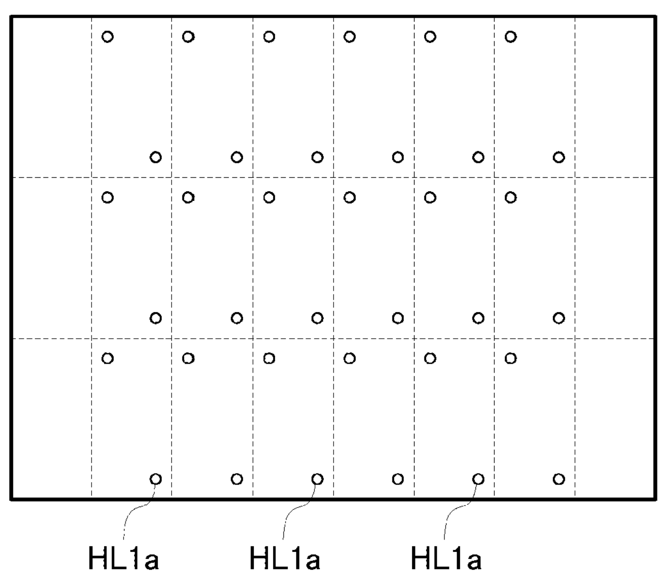


FIG. 6A FILL HOLES WITH CONDUCTIVE PASTE

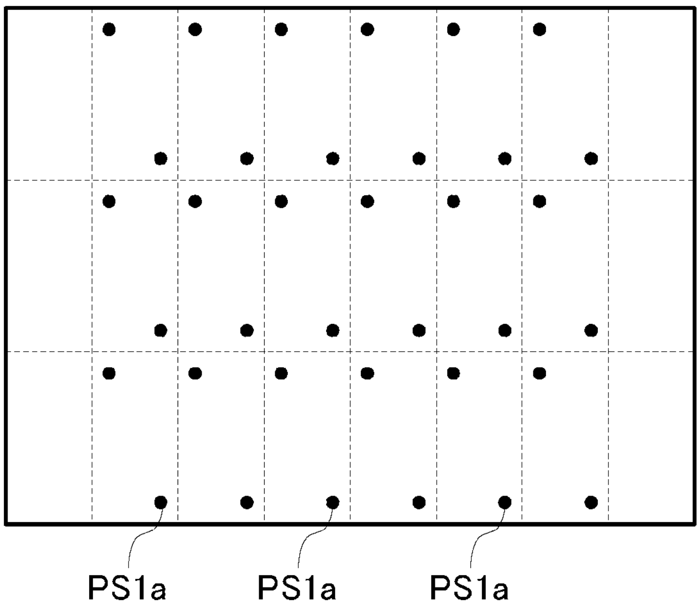


FIG. 6B PRINT COIL PATTERN

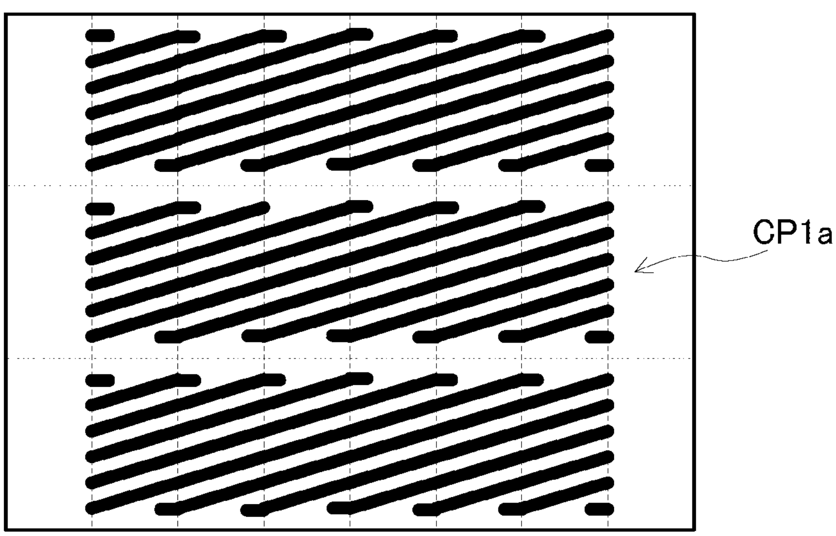


FIG. 7A PREPARE MOTHER SHEET

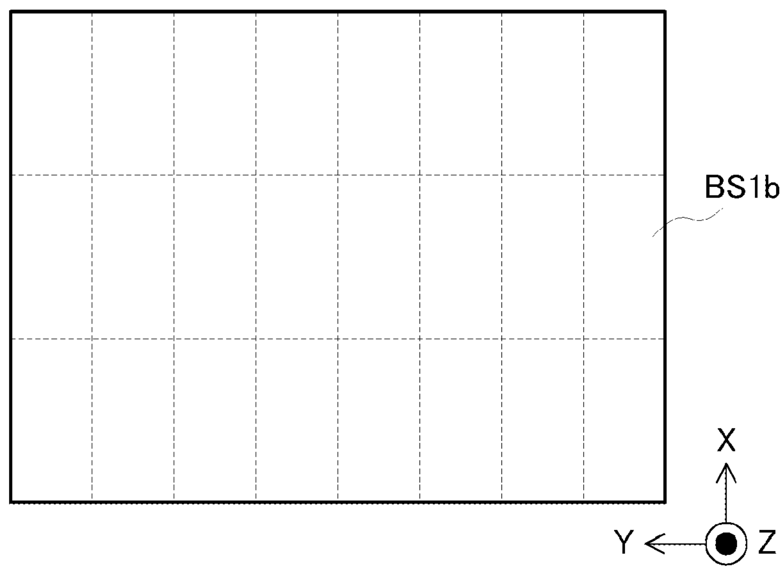


FIG. 7B FORM THROUGH-HOLES

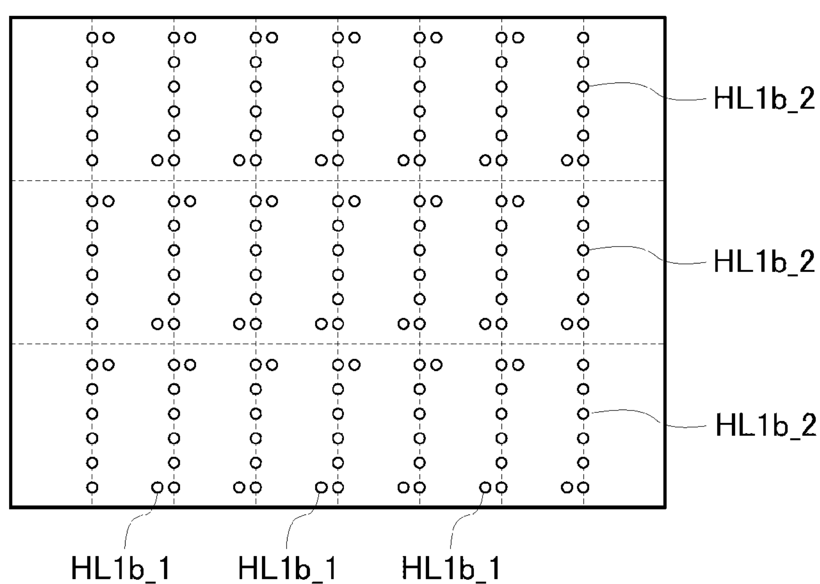


FIG. 8A FILL HOLES WITH CONDUCTIVE PASTE

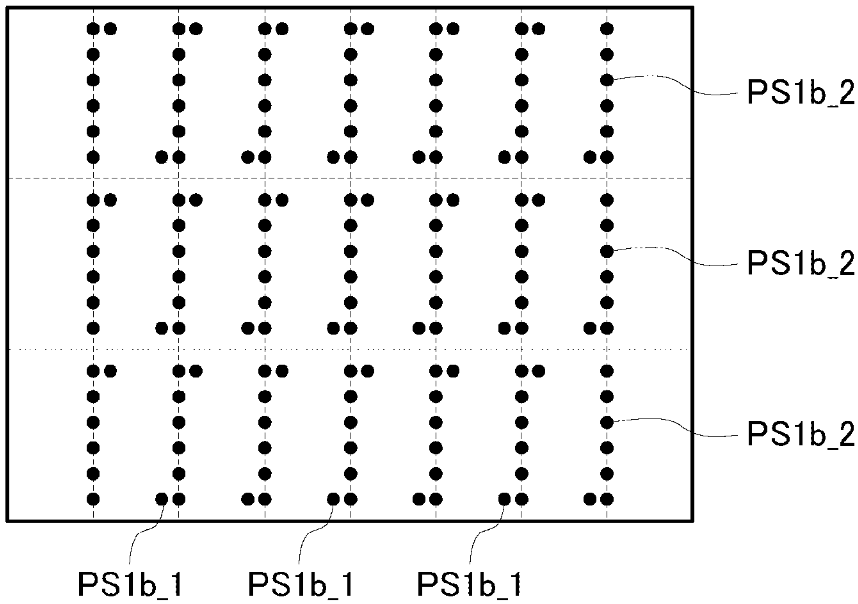


FIG. 8B PRINT COIL PATTERN

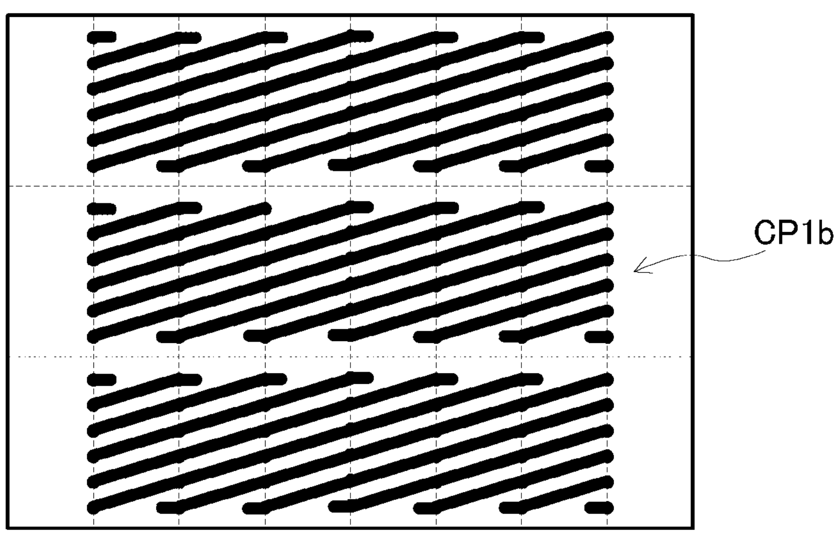


FIG. 9A PREPARE MOTHER SHEET

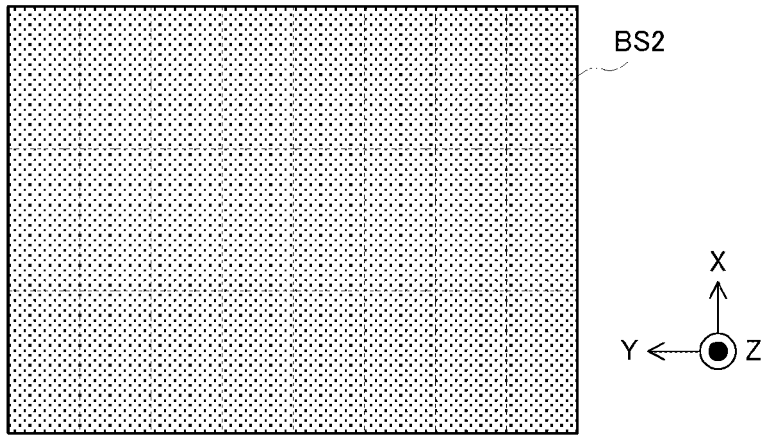


FIG. 9B FORM THROUGH-HOLES

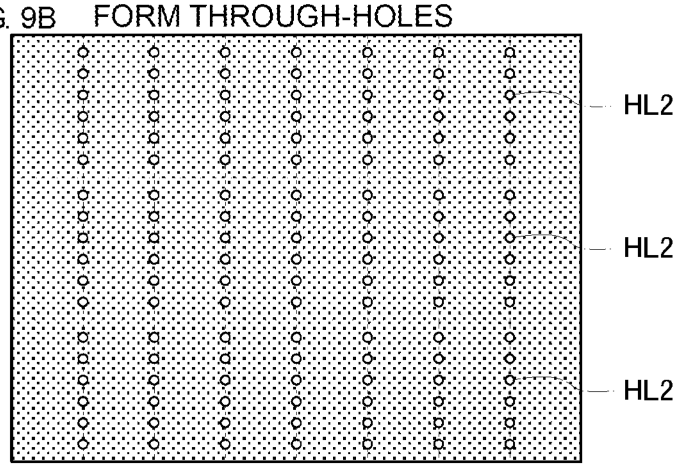


FIG. 9C FILL HOLES WITH CONDUCTIVE PASTE

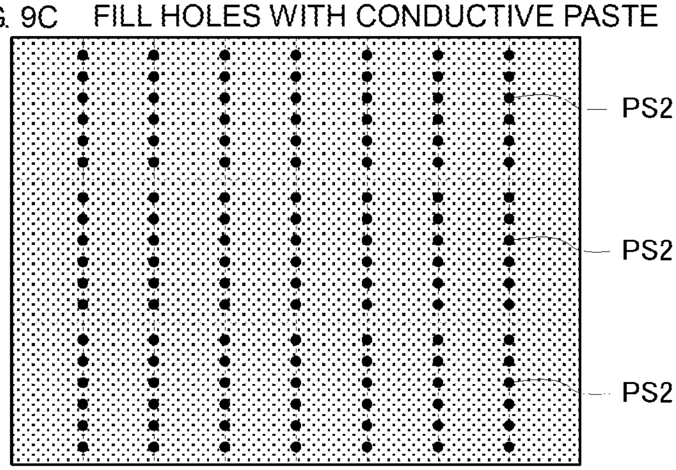


FIG. 10A PREPARE MOTHER SHEET

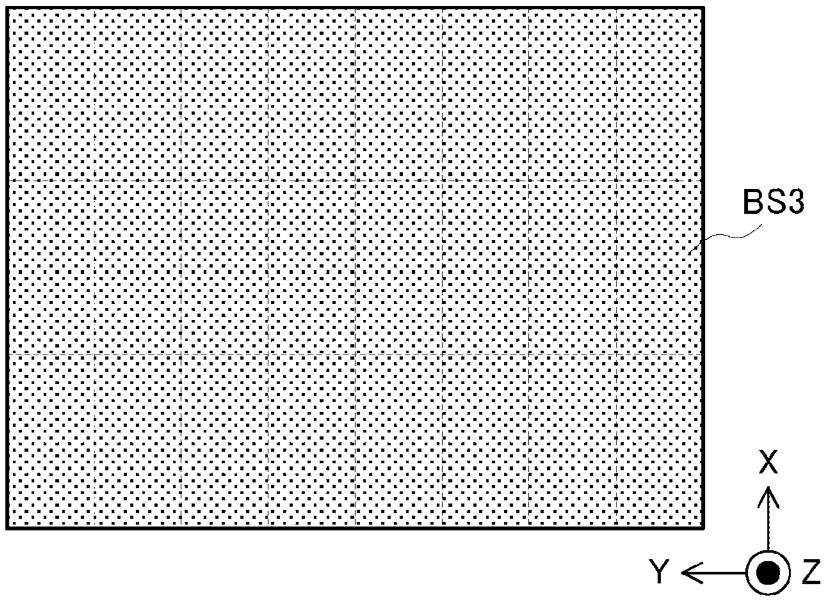


FIG. 10B FORM THROUGH-HOLES

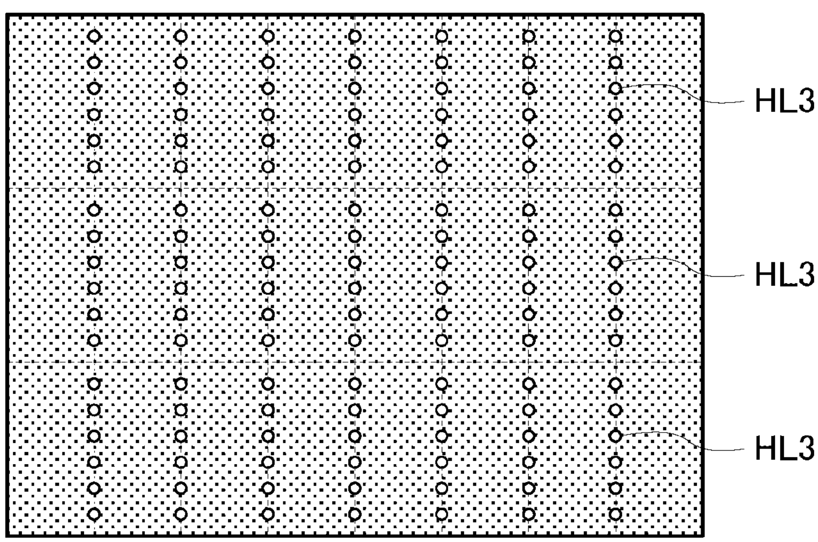


FIG. 11A FILL HOLES WITH CONDUCTIVE PASTE

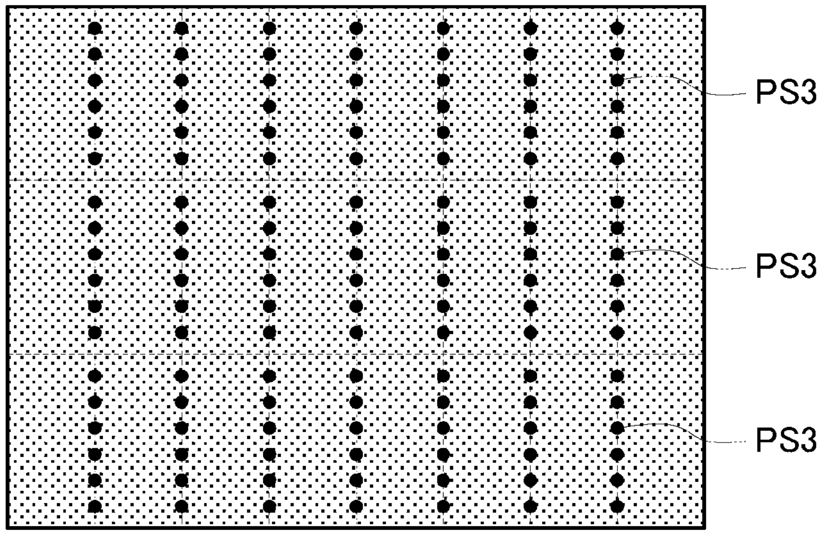


FIG. 11B PRINT COIL PATTERN

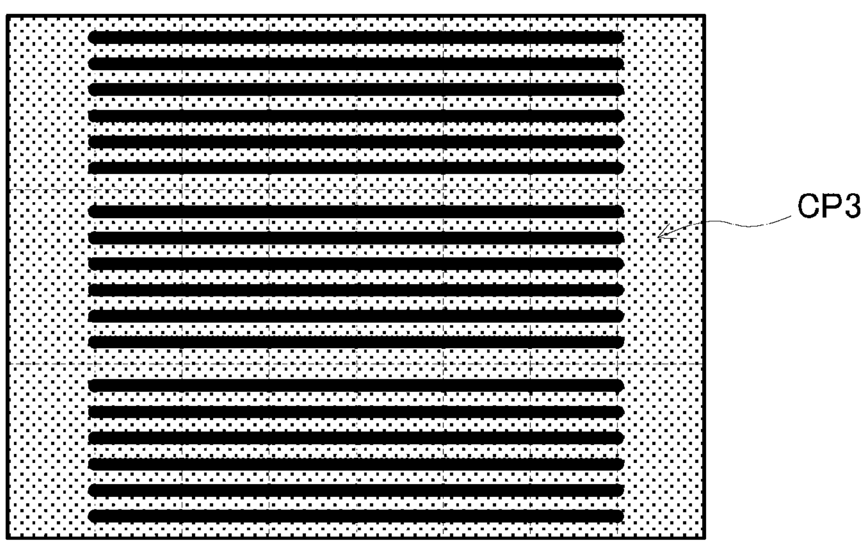


FIG. 12A PREPARE MOTHER SHEET

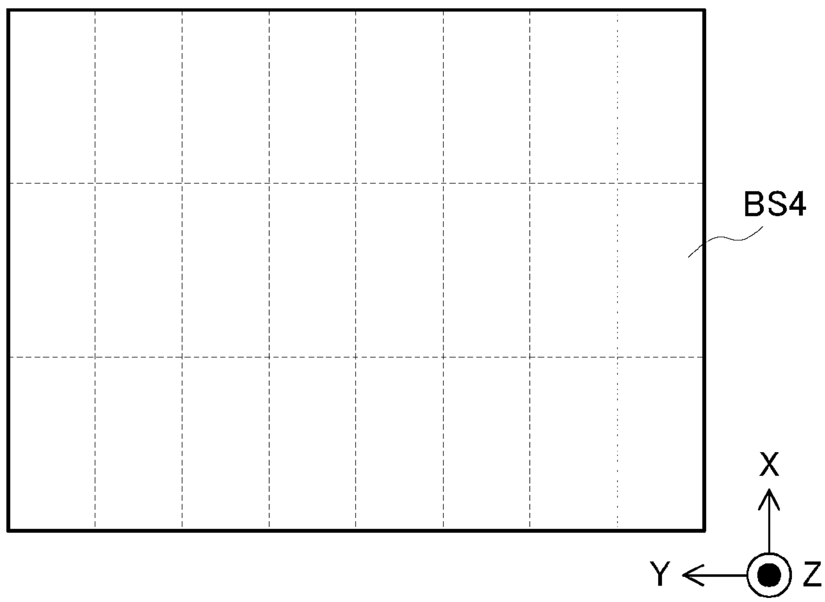


FIG. 12 B FORM THROUGH-HOLES

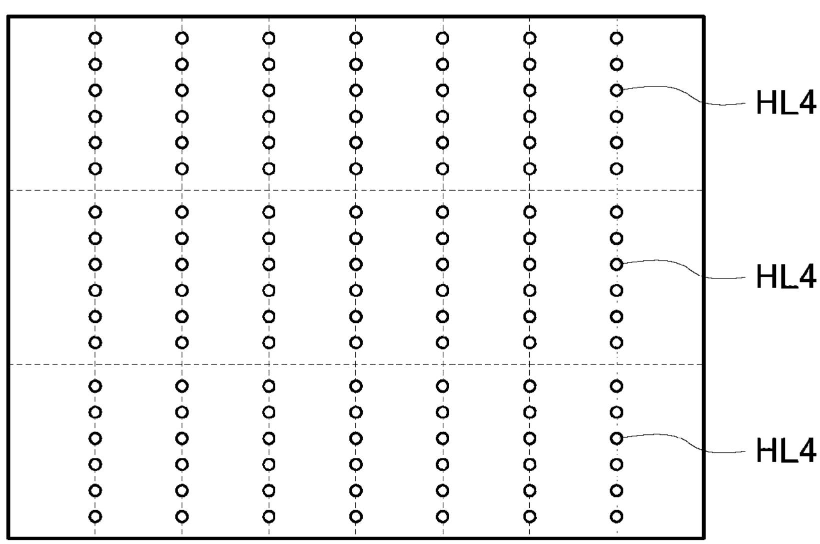


FIG. 13A FILL HOLES WITH CONDUCTIVE PASTE

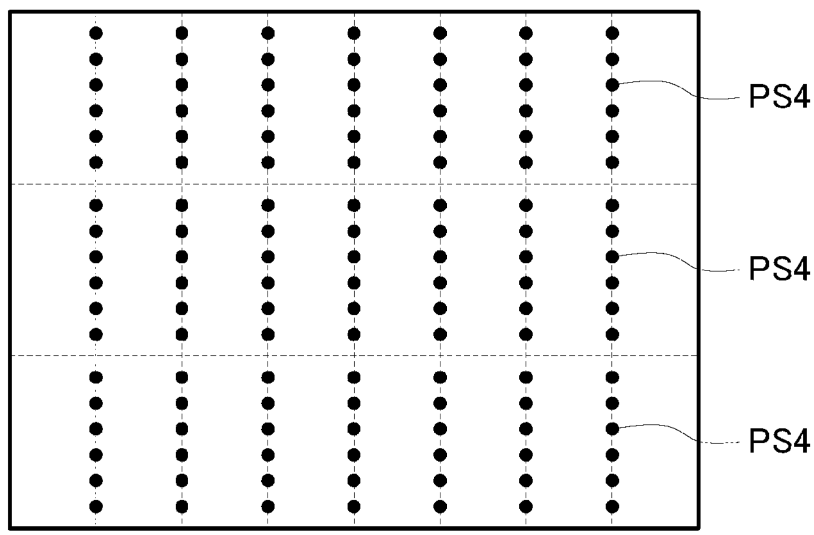


FIG. 13B PRINT COIL PATTERN

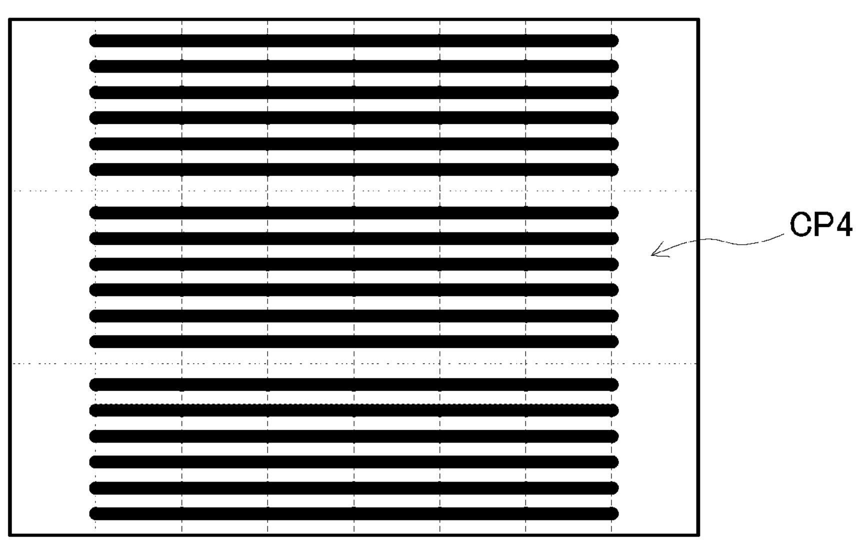


FIG. 14A STACK AND PRESS-BOND SHEETS

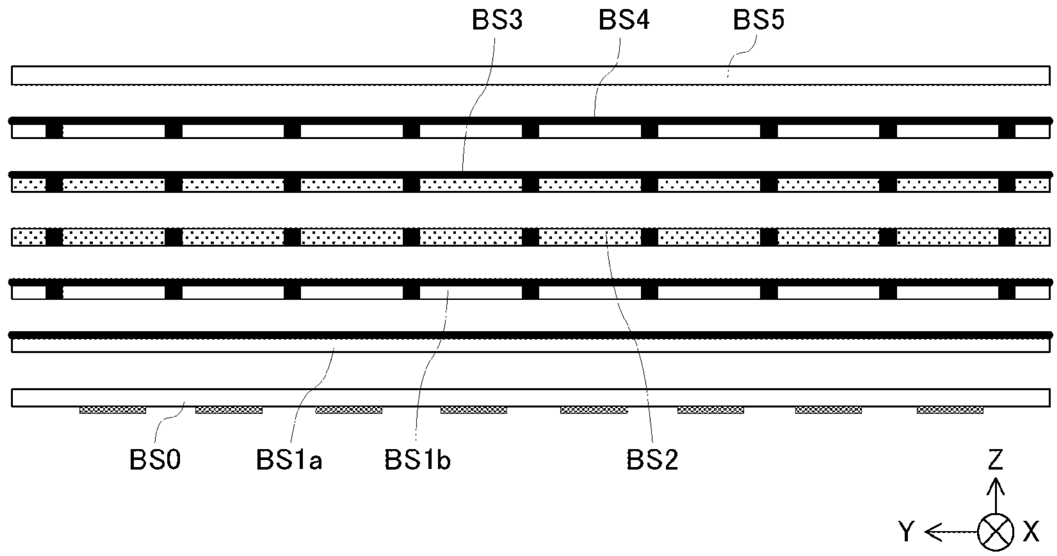


FIG.14B CUT MULTILAYER BODY INTO PIECES

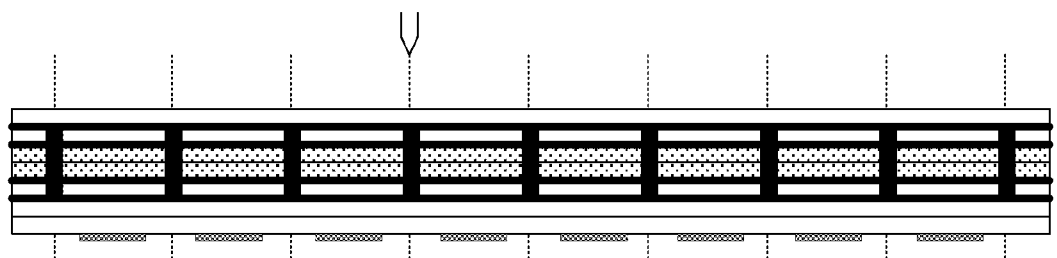
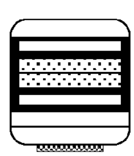


FIG.14C BARREL POLISHING & FIRING & PLATING



INDUCTOR ELEMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to inductor elements, and particularly relates to an inductor element that is applied as an antenna coil for near field communication.

2. Description of the Related Art

An example of this type of element is disclosed in Patent Document 1. According to this related art, an antenna coil includes a magnetic core and a coil that is wound therearound in the longitudinal direction of the magnetic core. The antenna coil is fabricated by winding, around a ferrite core, a resin film that is made of polyimide or the like and has a coil pattern printed thereon.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2008-35464

BRIEF SUMMARY OF THE INVENTION

However, according to the related art, a resin film is simply wound around a ferrite core, and thus the operation performance of the element is limited.

Accordingly, a major object of the present invention is to provide an inductor element that has enhanced operation performance.

An inductor element according to the present invention is an inductor element that includes a multilayer body including three or more sheets that are stacked one on top of another, each of the sheets having a principal surface provided with a plurality of linear conductors; and a plurality of via-hole conductors or side-surface conductors that are disposed with the multilayer body so as to connect the plurality of linear conductors to one another and form an inductor. The plurality of linear conductors have a pattern that is common among at least two sheets adjacent to each other in a stacking direction.

Preferably, the three or more sheets include one or more first sheets and a plurality of second sheets (SH**3** and SH**4**), each of the first sheets having a principal surface provided with a plurality of first linear conductors that are arranged at a predetermined interval in a first direction and that extend in a direction having a first angle with respect to the first direction, each of the second sheets having a principal surface provided with a plurality of second linear conductors that are arranged at the predetermined interval in a second direction and that extend in a direction having a second angle with respect to the second direction.

In a certain aspect, the first direction and the second direction match each other and the first sheets and the second sheets are stacked such that sheets of the same type are stacked one on top of another. Accordingly, the first linear conductors and the second linear conductors are alternately arranged along the principal surfaces when viewed from the stacking direction. A difference between a distance in the first direction from one end to another end of each of the first linear conductors and a distance in the second direction from one end to another end of each of the second linear conductors corresponds to the predetermined interval.

In another aspect, the one or more first sheets and the plurality of second sheets disposed between an inner side of the first linear conductors and an inner side of the second linear conductors are magnetic sheets.

In still another aspect, the one or more first sheets and the plurality of second sheets that are different from the one or more magnetic sheets disposed between an inner side of the first linear conductors and an inner side of the second linear conductors are nonmagnetic sheets.

According to the present invention, with a pattern of a plurality of linear conductors being common among at least two sheets, a plurality of protrusions having a pattern corresponding to this pattern are formed on a principal surface of an inductor element. Accordingly, the heat dissipation performance is enhanced. Further, with sheets provided with a plurality of linear conductors having a common pattern being adjacent to each other in a stacking direction, the plurality of linear conductors arranged in the stacking direction are connected in parallel to each other. Accordingly, DC resistance components of the inductor element are reduced, and the operation performance of the element is enhanced.

The above-described object and other objects, features, and advantages of the present invention will become more apparent from the detailed description of an embodiment that will be given with reference to the drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a diagram illustrating an exploded view of an inductor element according to this embodiment.

FIG. **2**A is a plan view illustrating an example of a nonmagnetic sheet SH**1***a* or SH**1***b* included in the inductor element, FIG. **2**B is a plan view illustrating an example of a magnetic sheet SH**3** included in the inductor element, and FIG. **2**C is a plan view illustrating an example of a nonmagnetic sheet SH**4** included in the inductor element.

FIG. **3** is a perspective view illustrating an appearance of the inductor element according to this embodiment.

FIG. **4** is a diagram illustrating the structure of an A-A cross section of the inductor element illustrated in FIG. **3**.

FIG. **5**A is a diagram illustrating a part of a manufacturing process of the nonmagnetic sheet SH**1***a*, and FIG. **5**B is a diagram illustrating another part of the manufacturing process of the nonmagnetic sheet SH**1***a*.

FIG. **6**A is a diagram illustrating another part of the manufacturing process of the nonmagnetic sheet SH**1***a*, and FIG. **6**B is a diagram illustrating still another part of the manufacturing process of the nonmagnetic sheet SH**1***a*.

FIG. **7**A is a diagram illustrating a part of a manufacturing process of the nonmagnetic sheet SH**1***b*, and FIG. **7**B is a diagram illustrating another part of the manufacturing process of the nonmagnetic sheet SH**1***b*.

FIG. **8**A is a diagram illustrating another part of the manufacturing process of the nonmagnetic sheet SH**1***b*, and FIG. **8**B is a diagram illustrating still another part of the manufacturing process of the nonmagnetic sheet SH**1***b*.

FIG. **9**A is a diagram illustrating a part of a manufacturing process of a magnetic sheet SH**2**, FIG. **9**B is a diagram illustrating another part of the manufacturing process of the magnetic sheet SH**2**, and FIG. **9**C is a diagram illustrating still another part of the manufacturing process of the magnetic sheet SH**2**.

FIG. **10**A is a diagram illustrating a part of a manufacturing process of the magnetic sheet SH**3**, and FIG. **10**B is a diagram illustrating another part of the manufacturing process of the magnetic sheet SH**3**.

FIG. **11**A is a diagram illustrating another part of the manufacturing process of the magnetic sheet SH**3**, and FIG. **11**B is a diagram illustrating still another part of the manufacturing process of the magnetic sheet SH**3**.

FIG. **12**A is a diagram illustrating a part of a manufacturing process of the nonmagnetic sheet SH**4**, and FIG. **12**B is a diagram illustrating another part of the manufacturing process of the nonmagnetic sheet SH**4**.

FIG. **13**A is a diagram illustrating another part of the manufacturing process of the nonmagnetic sheet SH**4**, and FIG. **13**B is a diagram illustrating still another part of the manufacturing process of the nonmagnetic sheet SH**4**.

FIG. **14**A is a diagram illustrating a part of a manufacturing process of the inductor element, FIG. **14**B is a diagram illustrating another part of the manufacturing process of the inductor element, and FIG. **14**C is a diagram illustrating still another part of the manufacturing process of the inductor element.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, a coil antenna element **10** according to this embodiment includes nonmagnetic sheets SH**0**, SH**1***a*, SH**1***b*, SH**4**, and SH**5**, and magnetic sheets SH**2** and SH**3**, each of which has rectangular principal surfaces. These sheets are stacked in order of "SH**0**", "SH**1***a*", "SH**1***b*", "SH**2**", "SH**3**", "SH**4**", and "SH**5**", and thereby a rectangular parallelepiped multilayer body **12** is fabricated. A long side and a short side of a rectangle that forms a principal surface of the multilayer body **12** extend along an X-axis and a Y-axis, respectively, and a thickness of the multilayer body **12** increases along a Z-axis. A lower surface of the multilayer body **12** is provided with conductor terminals **14***a* and **14***b*, which are located at both ends in the X-axis direction.

The sheets SH**0**, SH**1***a*, SH**1***b*, and SH**2** to SH**5** have principal surfaces of the same size. The sheets SH**0**, SH**1***a*, SH**1***b*, SH**4**, and SH**5** are made of a nonmagnetic ferrite, whereas the sheets SH**2** and SH**3** are made of a magnetic ferrite. Further, one principal surface and the other principal surface of the multilayer body **12** or the sheets SH**0**, SH**1***a*, SH**1***b*, and SH**2** to SH**5** are respectively referred to as an "upper surface" and a "lower surface" if necessary.

As illustrated in FIG. **2**A, a plurality of linear conductors **16** are disposed on the upper surfaces of the nonmagnetic sheets SH**1***a* and SH**1***b*. Also, as illustrated in FIG. **2**B, a plurality of linear conductors **18***a* are disposed on the upper surface of the magnetic sheet SH**3**. Further, as illustrated in FIG. **2**C, a plurality of linear conductors **18***b* are disposed on the upper surface of the nonmagnetic sheet SH**4**. No linear conductors exist on the upper surface of the magnetic sheet SH**2**, and a magnetic body is present over the entire upper surface. Likewise, no linear conductors exist on the upper surfaces of the nonmagnetic sheets SH**0** and SH**5**, and a nonmagnetic body is present over the entire upper surfaces.

The linear conductors **16** extend in a slanting direction with respect to the Y-axis and are arranged at an interval of a distance D**1** in the X-axis direction. Both ends in the length direction of each linear conductor **16** reach both edges in the Y-axis direction of the upper surface of the nonmagnetic sheet SH**1***a* or SH**1***b*. The two linear conductors **16** on both end sides in the X-axis direction are located on inner sides of both ends in the X-axis direction of the upper surface of the nonmagnetic sheet SH**1***a* or SH**1***b*.

The linear conductors **18***a* extend along the Y-axis and are arranged at an interval of the distance D**1** in the X-axis direction. Both ends in the length direction of each linear conductor **18***a* reach both edges in the Y-axis direction of the upper surface of the magnetic sheet SH**3**. The two linear conductors **18***a* on both end sides in the X-axis direction are located on inner sides of both ends in the X-axis direction of the upper surface of the magnetic sheet SH**3**.

The linear conductors **18***b* extend along the Y-axis and are arranged at an interval of the distance D**1** in the X-axis direction. Both ends in the length direction of each linear conductor **18***b* reach both edges in the Y-axis direction of the upper surface of the nonmagnetic sheet SH**4**. The two linear conductors **18***b* on both end sides in the X-axis direction are located on inner sides of both ends in the X-axis direction of the upper surface of the nonmagnetic sheet SH**4**.

The arrangement of the linear conductors **18***b* on the nonmagnetic sheet SH**4** matches the arrangement of the linear conductors **18***b* on the magnetic sheet SH3. Thus, the linear conductors **18***b* completely overlap the linear conductors **18***a* when viewed from the Z-axis direction.

In contrast, regarding the nonmagnetic sheet SH**1***a* or SH**1***b*, a distance in the X-axis direction from one end to the other end of each linear conductor **16** corresponds to "D**1**". In other words, the difference between the distance in the X-axis direction from one end to the other end of each linear conductor **16** and a distance in the X-axis direction from one end to the other end of each linear conductor **18***a* (or **18***b*) corresponds to "D**1**".

The position of one end of each linear conductor **16** is adjusted to a position that overlaps one end of a corresponding one of the linear conductors **18***a* or **18***b* when viewed from the Z-axis direction. The number of linear conductors **16** is smaller by one than the number of linear conductors **18***a* (=the number of linear conductors **18***b*).

Thus, when viewed from the Z-axis direction, the most part of each linear conductor **16** is sandwiched between two adjacent linear conductors **18***a* (or two adjacent linear conductors **18***b*). That is, when viewed from the Z-axis direction, the linear conductors **16** and **18***a* (or **18***b*) are alternately arranged in the X-axis direction.

On the upper surfaces of the nonmagnetic sheets SH**1***a* and SH**1***b*, plate-like conductors **20***a* and **20***b* are also disposed. The plate-like conductor **20***a* is disposed at a position that is a little toward the negative side of the positive end in the X-axis direction and at the positive edge in the Y-axis direction. The plate-like conductor **20***b* is disposed at a position that is a little toward the positive side of the negative end in the X-axis direction and at the negative edge in the Y-axis direction. A distance from the plate-like conductor **20***a* to one end of the linear conductor **16** that is at the most positive side in the X-axis direction corresponds to "D**1**", and also a distance from the plate-like conductor **20***b* to the other end of the linear conductor **16** that is at the most negative side in the X-axis direction corresponds to "D**1**".

As illustrated in FIG. **1**, the plate-like conductors **20***a* disposed on the individual nonmagnetic sheets SH**1***a* and SH**1***b* are connected to the conductor terminal **14***a* via a via-hole conductor **22***a*. Also, the plate-like conductors **20***b* disposed on the individual nonmagnetic sheets SH**1***a* and SH**1***b* are connected to the conductor terminal **14***b* via a via-hole conductor **22***b*.

Referring to FIG. **3**, a plurality of via-hole conductors (or side-surface conductors) **24***a* that extend in the Z-axis direction are disposed on a side surface on the positive side in the Y-axis direction of the multilayer body **12**. Also, a plurality of via-hole conductors (or side-surface conductors) **24***b* that extend in the Z-axis direction are disposed on a side surface on the negative side in the Y-axis direction of the multilayer body **12**.

The number of via-hole conductors **24***a* is the same as the number of linear conductors **18***a* (or linear conductors **18***b*), and the number of via-hole conductors **24***b* is the same as the number of linear conductors **18***a* (or linear conductors **18***b*). The individual via-hole conductors **24***a* and **24***b* are arranged at an interval of the distance D**1** in the X-axis direction. Further, the via-hole conductor **24***a* that is on the most positive side in the X-axis direction is connected to the plate-like conductors **20***a*, and the via-hole conductor **24***b* that is on the most negative side in the X-axis direction is connected to the plate-like conductors **20***b*.

Accordingly, the linear conductors **16** disposed on the nonmagnetic sheet SH**1***b*, the linear conductors **18***a* disposed on the magnetic sheet SH**3**, and the via-hole conductors **24***a* and **24***b* form a coil conductor (winding body). A magnetic body is disposed on an inner side of the coil conductor. Further, two linear conductors **16** that overlap each other when viewed from the Z-axis direction are connected in parallel to each other with a nonmagnetic body interposed therebetween. Also, two linear conductors **18***a* and **18***b* that overlap each other when viewed from the Z-axis direction are connected in parallel to each other with a nonmagnetic body interposed therebetween.

Referring to FIG. **4**, a plurality of protrusions CN**1** are disposed on the upper surface of the inductor element **10**. The protrusions CN**1** are arranged at an interval of the distance D**1** in the X-axis direction and extend along the Y-axis. Also, a plurality of protrusions CN**2** are disposed on the lower surface of the inductor element **10**. The protrusions CN**2** are arranged at an interval of the distance D**1** in the X-axis direction and extend in a slanting direction with respect to the Y-axis.

The protrusions CN**1** and CN**2** are formed as a result of stacking a plurality of sheets having a common conductor pattern. The protrusions CN**1** and CN**2** are formed at the time when firing (described below) is completed. As a result of forming the protrusions CN**1** and CN**2** in this way, the heat dissipation performance of the inductor element **10** is enhanced. Further, as a result of connecting in parallel two linear conductors **16** (or **18***a* and **18***b*) that overlap each other when viewed from the Z-axis direction, DC resistance components of the inductor element **10** are reduced. Accordingly, the operation performance of the inductor element **10** can be enhanced.

The nonmagnetic sheet SH**1***a* is fabricated in the manner illustrated in FIG. **5**A, FIG. **5**B, FIG. **6**A, and FIG. **6**B. First, a ceramic green sheet made of a nonmagnetic ferrite material is prepared as a mother sheet BS**1***a* (see FIG. **5**A). Here, a plurality of broken lines extending in the X-axis direction and the Y-axis direction indicate cutting positions.

Subsequently, a plurality of through-holes HL**1***a* are formed at positions near intersections of the broken lines in the mother sheet BS**1** (see FIG. **5**B), and the through-holes HL**1***a* are filled with a conductive paste PS**1***a* (see FIG. **6**A). The conductive paste PS**1***a* that has filled the through-holes HL**1***a* forms the via-hole conductor **22***a* or **22***b*.

After filling with the conductive paste PS**1***a* has been completed, a coil pattern CP**1***a* that forms the linear conductors **16** and the plate-like conductors **20***a* and **20***b* is printed on one principal surface of the mother sheet BS**1***a* (see FIG. **6**B).

The nonmagnetic sheet SH**0** is fabricated by forming through-holes that are the same as the through-holes HL**1***a* illustrated in FIG. **5**B in a mother board, filling the through-holes with a conductive paste, and printing the conductor terminals **14***a* and **14***b* on the lower surface of the mother board.

The nonmagnetic sheet SH**1***b* is fabricated in the manner illustrated in FIG. **7**A, FIG. **7**B, FIG. **8**A, and FIG. **8**B. First, a ceramic green sheet made of a nonmagnetic ferrite material is prepared as a mother sheet BS**1***b* (see FIG. **7**A). Here, a plurality of broken lines extending in the X-axis direction and the Y-axis direction indicate cutting positions.

Subsequently, a plurality of through-holes HL**1***b*_**1** are formed near intersections of the broken lines in the mother sheet BS**1***b*, and a plurality of through-holes HL**1***b*_**2** are formed along the broken lines extending in the X-axis direction in the mother sheet BS**1***b* (see FIG. **7**B). The through-holes HL**1***b*_**1** are filled with a conductive paste PS**1***b*_**1**, and the through-holes HL**1***b*_**2** are filled with a conductive paste PS**1***b*_**2** (see FIG. **8**A). The conductive paste PS**1***b*_**1** forms the via-hole conductor **22***a* or **22***b*, and the conductive paste PS**1***b*_**2** forms the via-hole conductors **24***a* or **24***b*.

After filling with the conductive paste PS**1***b*_**1** or PS**1***b*_**2** has been completed, a coil pattern CP**1***b* that forms the linear conductors **16** and the plate-like conductors **20***a* and **20***b* is printed on one principal surface of the mother sheet BS**1***b* (see FIG. **8**B).

The magnetic sheet SH**2** is fabricated in the manner illustrated in FIG. **9**A to FIG. **9**C. First, a ceramic green sheet made of a magnetic ferrite material is prepared as a mother sheet BS**2** (see FIG. **9**A). Here, a plurality of broken lines extending in the X-axis direction and the Y-axis direction indicate cutting positions. Subsequently, a plurality of through-holes HL**2** are formed along the broken lines extending in the X-axis direction in the mother sheet BS**2** (see FIG. **9**B), and the through-holes HL**2** are filled with a conductive paste PS**2** that forms the via-hole conductors **24***a* or **24***b* (see FIG. **9**C).

The magnetic sheet SH**3** is fabricated in the manner illustrated in FIG. **10**A, FIG. **10**B, FIG. **11**A, and FIG. **11**B. First, a ceramic green sheet made of a magnetic ferrite material is prepared as a mother sheet BS**3** (see FIG. **10**A). Here, a plurality of broken lines extending in the X-axis direction and the Y-axis direction indicate cutting positions.

Subsequently, a plurality of through-holes HL**3** are formed along the broken lines extending in the X-axis direction in the mother sheet BS**3** (see FIG. **10**B), and the through-holes HL**3** are filled with a conductive paste PS**3** that forms the via-hole conductors **24***a* or **24***b* (see FIG. **11**A). After filling with the conductive paste PS**3** has been completed, a coil pattern CP**3** that forms the linear conductors **18***a* is printed on one principal surface of the mother sheet BS**3** (see FIG. **11**B).

The nonmagnetic sheet SH**4** is fabricated in the manner illustrated in FIG. **12**A, FIG. **12**B, FIG. **13**A, and FIG. **13**B. First, a ceramic green sheet made of a nonmagnetic ferrite material is prepared as a mother sheet BS**4** (see FIG. **12**A). Here, a plurality of broken lines extending in the X-axis direction and the Y-axis direction indicate cutting positions.

Subsequently, a plurality of through-holes HL**4** are formed along the broken lines extending in the X-axis direction in the mother sheet BS**4** (see FIG. **12**B), and the through-holes HL**4** are filled with a conductive paste PS**4** that forms the via-hole conductors **24***a* or **24***b* (see FIG. **13**A). After filling with the conductive paste PS**4** has been completed, a coil pattern CP**4** that forms the linear conductors **18***b* is printed on one principal surface of the mother sheet BS**4** (see FIG. **13**B).

The mother sheets BS**1***a*, BS**1***b*, and BS**2** to BS**4** that have undergone the above-described steps, a mother sheet BS**0** corresponding to the nonmagnetic sheet SH**0**, and a mother sheet BS**5** corresponding to the nonmagnetic sheet SH**5** are press-bonded to one another with being stacked in the manner illustrated in FIG. **14**A. According to FIG. **14**A, the mother sheets BS**0**, BS**1***a*, BS**1***b*, and BS**2** to BS**5** are stacked in this order. At this time, the stacking positions of the individual sheets are adjusted so that the broken lines assigned to the individual sheets overlap one another when viewed from the Z-axis direction.

The multilayer body obtained through the press-bonding is cut along the above-described broken lines into individual pieces before firing (see FIG. **14**B). After that, the individual pieces undergo a series of processes including barrel polishing, firing, and plating (see FIG. **14**C), and accordingly the inductor element **10** is completed.

As is understood from the description given above, the multilayer body **12** includes the nonmagnetic sheets SH**1***a* and SH**1***b* each having the upper surface provided with the plurality of linear conductors **16**; the magnetic sheet SH**3** having the upper surface provided with the plurality of linear conductors **18***a*; and the nonmagnetic sheet SH**4** having the upper surface provided with the plurality of linear conductors **18***b*, which are stacked one on top of another. The plurality of via-hole conductors **24***a* and **24***b* are disposed in the multilayer body **12** so as to connect these linear conductors to one another and form an inductor. Here, the plurality of linear conductors have a pattern that is common among at least two sheets adjacent to each other in the stacking direction.

With a pattern of a plurality of linear conductors being common among at least two sheets, the plurality of protrusions CN**1** and CN**2** having a pattern corresponding to this pattern are formed on the principal surfaces of the inductor element **10**. Accordingly, the heat dissipation performance is enhanced. Further, with sheets provided with a plurality of linear conductors having a common pattern being adjacent to each other in the stacking direction, a plurality of linear conductors arranged in the stacking direction are connected in parallel to each other. Accordingly, DC resistance components of the inductor element **10** are reduced, and the operation performance of the inductor element **10** is enhanced.

More specifically, the plurality of linear conductors **16** that are arranged at an interval of the distance D**1** in the X-axis direction and that extend in a slanting direction with respect to the Y-axis are disposed on the upper surfaces of the nonmagnetic sheets SH**1***a* and SH**1***b*. Also, the plurality of linear conductors **18***a* or **18***b* that are arranged at an interval of the distance D**1** in the X-axis direction and that extend in the Y-axis direction are disposed on the upper surfaces of the magnetic sheet SH**3** and the nonmagnetic sheet SH**4**.

Here, the nonmagnetic sheets SH**1***a* and SH**1***b* and the magnetic sheet SH**3** and the nonmagnetic sheet SH**4** are stacked such that sheets of the same type are stacked one on top of another and that the linear conductors **16** and **18***a* (or **18***b*) are alternately arranged along the upper surfaces when viewed from the Z-axis direction. The difference between the distance in the X-axis direction from one end to the other end of each linear conductor **16** and the distance in the X-axis direction from one end to the other end of each linear conductor **18***a* (or **18***b*) corresponds to the distance D**1**. Further, the via-hole conductors **24***a* that extend from one ends of the linear conductors **16** in the Z-axis direction and the via-hole conductors **24***b* that extend from the other ends of the linear conductors **16** in the Z-axis direction are disposed in the multilayer body **12**.

With a plurality of sheets having a common conductor pattern being stacked one on top of another, the plurality of protrusions CN**1** that are arranged at an interval of the distance D**1** in the X-axis direction and that extend in the Y-axis direction are formed on the upper surface of the inductor element **10**. Accordingly, the heat dissipation performance is enhanced. Further, with the via-hole conductors **24***a* and **24***b* that respectively extend from one ends and the other ends of the linear conductors **16** in the Z-axis direction being disposed, a coil conductor is formed, and two linear conductors **16** or two linear conductors **18***a* and **18***b* that exist at the same position viewed from the Z-axis direction are connected in parallel to each other. Accordingly, DC resistance components of the inductor element **10** are reduced, and the operation performance of the element can be enhanced.

In this embodiment, the nonmagnetic sheets SH**1***a* and SH**1***b* that have a common conductor pattern are stacked one on top of another, and also the magnetic sheet SH**3** and the nonmagnetic sheet SH**4** that have another common conductor pattern are stacked one on top of another. However, the heat dissipation performance is enhanced if at least one of the nonmagnetic sheets SH**1***a* and SH**4** exists. Thus, one of the nonmagnetic sheets SH**1***a* and SH**4** may be used, and the other may be omitted.

In this embodiment, the linear conductors **16** extend in a slanting direction with respect to the Y-axis, whereas the linear conductors **18***a* and **18***b* extend in the Y-axis direction. However, the linear conductors **18***a* and **18***b* may extend in a slanting direction as long as the difference between the distance in the X-axis direction from one end to the other end of each linear conductor **16** and the distance in the X-axis direction from one end to the other end of each linear conductor **18***a* (or **18***b*) is adjusted to D**1**.

Further, in this embodiment, the via-hole conductor **24***a* that exists on the most positive side in the X-axis direction is connected to the conductor terminal **14***a* via the plate-like conductors **20***a* and the via-hole conductor **22***a*, and the via-hole conductor **24***b* that exists on the most negative side in the X-axis direction is connected to the conductor terminal **14***b* via the plate-like conductors **20***b* and the via-hole conductor **22***b* (see FIG. **1**, FIG. **2**A, and FIG. **3**). However, in a case where side-surface conductors of the inductor element **10** are mounted as terminal electrodes on a printed wiring board, the plate-like conductors **20***a* and **20***b*, the via-hole conductors **22***a* and **22***b*, and the conductor terminals **14***a* and **14***b* are not necessary.

The present invention has been described and illustrated in detail. It is obvious that the description and illustration have been given merely as illustration and an example, and should not be interpreted as limitation. The spirit and scope of the present invention are limited only by the description of the attached claims.

10 inductor element
SH**0**, SH**1***a*, SH**1***b*, SH**4**, SH**5** nonmagnetic sheet
SH**2**, SH**3** magnetic sheet
16, **18***a*, **18***b* linear conductor
22*a*, **22***b*, **24***a*, **24***b* via-hole conductor

The invention claimed is:

1. An inductor element comprising:

a multilayer body including three or more sheets that are stacked one on top of another, each of the sheets having a principal surface provided with a plurality of linear conductors; and

a plurality of via-hole conductors that are disposed with the multilayer body so as to connect the plurality of linear conductors to one another to form the inductor; and

a plurality of protrusions on upper and lower surfaces of the multilayer body arranged at a same interval,

wherein the plurality of linear conductors have a pattern that is common among at least two sheets adjacent to each other in a stacking direction,

the plurality of protrusions have a protrusion pattern corresponding to the pattern of the plurality of linear conductors that is common among the at least two sheets adjacent to each other,

a nonmagnetic body is disposed between adjacent ones of the plurality of linear conductors having the pattern that is common among the at least two sheets adjacent to each other in the stacking direction,

the three or more sheets include one or more first sheets and a plurality of second sheets, each of the first sheets has a principal surface provided with a plurality of first linear conductors that are arranged at a same interval in a first direction and that extend in a direction having a first angle with respect to the first direction,

each of the second sheets has a principal surface provided with a plurality of second linear conductors that are arranged at a same interval in a second direction and that extend in a direction having a second angle with respect to the second direction,

the first linear conductors and second linear conductors form a coil conductor,

the one or more first sheets and the plurality of second sheets disposed on an inner side of the coil conductor comprise one or more magnetic sheets, and

the plurality of via-hole conductors arranged at the one or more magnetic sheets are side surface conductors.

2. The inductor element according to claim **1**,

wherein the first direction matches the second direction,

wherein the first sheets and the second sheets are stacked such that sheets of the same type are stacked one on top of another and that the first linear conductors and the second linear conductors are alternately arranged along the principal surfaces when viewed from the stacking direction, and

wherein a difference between a distance in the first direction from one end to another end of each of the first linear conductors and a distance in the second direction from one end to another end of each of the second linear conductors corresponds to the same interval.

3. The inductor element according to claim **1**,

wherein, the one or more first sheets and the plurality of second sheets that are different from one or more sheets disposed on an inner side of the coil conductor comprise one or more nonmagnetic sheets.

4. The inductor element according to claim **2**,

wherein the first linear conductors and second linear conductors form a coil conductor.

5. The inductor element according to claim **4**,

wherein, the one or more first sheets and the plurality of second sheets disposed on an inner side of the coil conductor comprise one or more magnetic sheets.

6. The inductor element according to claim **4**,

wherein, the one or more first sheets and the plurality of second sheets that are different from one or more sheets disposed on an inner side of the coil conductor comprise one or more magnetic sheets.

7. The inductor element according to claim **1**,

wherein, the one or more first sheets and the plurality of second sheets that are different from the one or more sheets disposed on the inner side of the coil conductor comprise one or more nonmagnetic sheets.

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